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(54) IMPROVED FIBRE OPTICS T-COUPLER

(71) We, PATELHOLD PATENTVERWERTUNGS-& ELEKTRO HOLDING AG, a Swiss company of Glarus, Switzerland, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to an optical-fibre T-coupler comprising solid-glass cores and reflective systems. Fibre-optics T-couplers are already known in embodiments including guide members and also with reflective arrangements. For example, in U.S. patent specification 3 883 217 there are described T-couplers in which two solid-glass cores arranged in series are interposed between the terminal surfaces of an interrupted primary fibre bundle and have the light guides of the coupled branches (receiver/transmitter) and also a direct connection applied to their inner surfaces. The incoming light signal is thus divided into a component led to the receiver and a component passing directly through the coupler. The light passing directly through the coupler and the transmitter signal injected in the same direction combine into a new transmitted signal at the coupler output. The two series-arranged solid-glass cores have the function of a diffuser (randomiser, scrambler). Beyond a certain length of core light entering at any point is distributed over the whole core cross-section and thus passes uniformly into all the fibres of the outgoing fibre bundle. The relatively complex construction is a disadvantage. Six individual components are present in the device, of which the end faces must be exactly aligned and cemented. Even the construction of the fibre bundle providing the direct connection is not without problems.

In accordance with U.S. patent specification 3 870 396 right-angled isosceles glass prisms are interposed in the primary fibre bundle and the hypotenuse surfaces, positioned inclinedly to the direction of the transmitted light, or bridged by a reflector. This reflector is only partly reflective at the position at which the receiver signal is coupled out and is fully reflective at the position for the introduction of the transmitter signal. The arrangement is directional, so that two such couplers are necessary for duplex working. The large coupling cross-sections which must subsequently be reduced, by way of guide transition sections (naturally accompanied by radiation losses or reflections) to the cross-section of the outgoing fibre bundle are a disadvantage. Exact adjustment of the individual coupling conditions at the partly transmissive reflector can also be far from simple.

A principle disadvantage of the T-coupler is known to be the relatively high transmission attenuation of 3-4 dB resulting from the losses through the spacer and sheathing cross-section of the outgoing fibre bundle. Applications may be envisaged, however, in which these characteristics are of less importance.

It is the object of the invention to provide an optical T-coupler which includes few individual components, does not require special alignment and may be cheaply manufactured.

According to the present invention there is provided a fibre-optics T-coupler comprising a primary guide and at least one branch guide, the or each branch guide extending at an angle of substantially 90° to the primary guide and a reflective surface being arranged at the position of the or each branch guide at an angle of substantially 45° to the primary guide so as to deflect, from or into the primary guide, a portion of the light transmitted along the primary guide, the deflected portion being deflected by substantially 90° into or from the branch guide at that position, and wherein at the or each branch position the primary guide comprises a one-piece element of solid transparent material extending in opposite directions away from that position and the branch guide comprises a one-piece element

of solid transparent material extending away from that position.

The invention will be further explained with reference to the accompanying drawings comprising Figures 1—6, in which housings and any necessary mountings are not shown for the sake of simplicity in illustration. In the drawings:

Figures 1*a* and 1*b* show two schematic views of a coupler operating on the principle of coupling light in and out by means of a reflector system positioned in the side of the coupler opposite the branch connection;

Figure 2 shows how the principle of Figures 1*a* and 1*b* may be modified for directional coupling;

Figures 3*a* and 3*b* show two schematic views of a coupler operating on the principle of coupling light in and out by means of a reflector system positioned on the side of the coupler adjacent the branch connection;

Figure 4 shows how the principle of Figures 3*a* and 3*b* may be modified for directional coupling;

Figures 5*a* and 5*b* show two schematic views of a coupler operating on the principle of coupling light in and out by means of a reflector system arranged within the solid core; and

Figure 6 shows how the principle of Figures 5*a* and 5*b* may be modified for directional coupling.

In the embodiment shown in Figures 1*a* and 1*b*, reference 1 denotes a solid glass core element included in the primary transmission path and 2 denotes a branch leading for example to a receiver, the branch likewise being in the form of a solid glass core element. Opposite the position of the branch 2 there is formed in the core 1 a triangular notch 3, of which the surfaces 4 are inclined to the axis of the light guide at an angle which is at least approximately 45° and are mirror-coated. Thus, as is indicated by arrowed lines, a part of the light entering the core 1 is deflected into the core 2. The solid cores are arranged as diffuser rods, that is, their length, taken from the coupling point to the coupled fibre bundles (not shown in Figures 1*a* and 1*b*) should be at least 10 times their respective diameters. Core 2 is advantageously optically coupled to core 1 by cement indicated at 11.

In the arrangement shown in Figure 2, two separate couplings 2*a*, 2*b* are provided on the primary core, for the purpose of directionally separate coupling in and coupling out of light, for example, in networks of ring form. For this purpose the solid core 1 is trapezoidally recessed about its centre. The terminal faces 4*a*, 4*b* of the recess are inclined at 45° opposite the positions of the T-couplers 2*a*, 2*b* while the long face bounds the direct connection 5 extending between the two T-couplers. At the reflective surface 4*a* a part of the incident light is, as illustrated, deflected at a right angle into the guide 2*a* leading to the receiver E by the reflector 4*b*, the light signal coming, from the transmitter S over the guide 2*b* is injected into the primary guide again in the original direction of transmission. The cross-section of the direct connection 5 is just so much smaller compared with the full cross-section of the primary core 1 as the percentage of the light intensity received in the coupler that is diverted by means of the reflector 4*a* into the receiver branch. At the position at which the transmitter is coupled-in by means of the reflector 4*b* the smaller cross-section of the connection 5 is again made up to the full cross-section of the coupler output. Under these conditions the losses for light which traverses the coupler directly are a minimum. By means of the relative diminution of cross-section of the connection 5, the power coupled-out to the receiver may be given a predetermined ratio to the light intensity incident on the coupler.

The coupling of the branch core 2 (Figure 1) or of the cores 2*a*, 2*b* (Figure 2) to the primary core 1 is not critical. In any case, however, the optical relations must be such that the received light is as far as possible fully made use of. There are in principle several possibilities, in accordance with the degree of coupling. With strong coupling (e.g. 3dB corresponding to half the primary cross-section) the transition should be optically homologous, which can readily be achieved by cementing, as indicated at 11, in Figure 1. For weaker coupling on the other hand, it is possible, as indicated in Figure 2, for the branch cores 2*a*, 2*b* merely to abut the primary core 1, without cementing. The curvature of the surface of the primary core opposed to the reflective surfaces in fact effects a considerable focusing of the incident light, as in a cylindrical lens. In addition, it is possible appropriately to curve the reflector surfaces convexly in the longitudinal direction of the primary guide 1, so that light transmission similar to a plano-convex lens results.

In the coupler systems in accordance with Figures 3*a*, 3*b* and 4, the recesses in the primary guide 1 are of rectangular form and are placed on the side of the guide turned towards the coupling guides. Here the reflector surfaces for deflecting the light are, as shown, on the end faces of the coupled guides. Figure 3 shows the construction for bi-directional transmission, Figure 4 the arrangement for directionally separated transmission. Preferably, a rectangular or square cross-section of the guides is used here, since optimum conditions for light transmission can then be easily achieved. The mode of operation is in general the same as

for the arrangements of Figures 1*a*, 1*b* and 2.

Finally, Figures 5*a*, 5*b* and 6 show arrangements in which the 45° diverting reflectors are arranged concentrically in a circular primary core. Both of the systems are arranged for directionally separate operation. In Figures 5*a* and 5*b* the primary core is pierced at right angles by the two coupling guides 6*a*, 6*b*. Between the end surfaces of the two guides, inclined at 45°, is a metal foil 7 reflective on both sides, which as indicated deflects the incident light appropriately for both directions. A thin air-gap may be employed instead of the foil, reflection then resulting from the difference in the refractive indices of the material of the guides 6*a*, 6*b* and of air. The degree of coupling to the receiver is again determined by the ratio of the diverted cross-section to the full primary cross-section.

In the construction shown in Figure 6, the primary core is divided into two preferably similar portions 1*a*, 1*b*. From the meeting plane there are formed blind bores which contain light-transmissive inserts 8*a*, 8*b*, as well as a preferably metallic supporting peg 9, of which the ends 7*a*, 7*b*, sloped at 45° are reflective. Light falling on the reflective surfaces 7*a*, 7*b* is thus, as indicated, diverted into the guide 6*a* to the receiver E and from the transmitter S over the guide 6*b* into the primary core portion 1*b*. With accurate optical cementing of the components 8*a* 8*b* and 9 with guide portions 1*a*, 1*b* only the reflective surfaces 7*a*, 7*b* appear in the light transmission path. In principle the inserts 8*a*, 8*b* could even be omitted, but this would necessitate exact optical finishing of the end faces of the blind bores, or the supporting peg 9 could be provided with perpendicular end surfaces and the 45° end surfaces of the inserts 8*a*, 8*b* could be made reflective, and so on, though however, no substantial advantage would result. For light transfer between the coupling guides 6*a*, 6*b* and the primary core 1, the lens effect of the surface curvature of the primary core already explained with reference to Figure 1, is advantageously made use of. With additional cylindrical curvature of the reflective surfaces 7*a*, 7*b* in the plane containing the incident and reflected beams there may again be obtained a focusing action similar to that of a plano-convex lens. It is true that this assumes that the two inserts 8*a*, 8*b* are present so that the material in the vicinity of the reflective surface has about the refractive index of the primary core. In addition, the coupling guides 6*a*, 6*b* may also be mutually rotated through any angle, instead of lying in one plane, as shown. The concentric introduction into the primary core 1*b* of the light transmitted directly into the coupler through the connection 10 surrounding the blind bores and of the transmitter signal coupled in by way of the reflector 7*b* effects advantageous homogenisation of the light distribution particularly suitably. The amount of receiver coupling is determined in principle by the width of the blind bore in comparison to the fully primary cross-section.

The possibilities are shown in principle in the first place by the arrangements represented in Figures 1–6. In addition, other analagous modifications are also possible, for example, to form on the primary core 1 two sawtooth-shaped recesses at diametrally opposed positions, each having a 45° inclination, or to form the trapezoidal or rectangular recesses in the primary core (in accordance with Figure 2 or Figure 4) merely as grooves. Any transparent material (silicate glass, transparent acrylic material) may be used as the solid-glass core. Instead of being circular in form the guide cross-sections may if necessary be square or rectangular, the ends of the fibre bundle may readily be adapted to either form. For the purpose of homogenising the mixing of the light the solid core may in addition contain suspended light-scattering centres or diffusing plates arranged at certain distances, forming a milky translucent material. In some cases optically true surfaces of the guide material may be used instead of mirrors for diversion of the light, so that the reflection takes place as a result of the difference in the refractive indices of the guide material and of the surrounding air.

While the degree of coupling of the receiver corresponds more or less to the ratio of the coupling surface to the primary transmission cross-section, the coupling co-efficient for, the transmitter is practically equal to unity. This difference is significant insofaras, in a linear fibre network, large section attenuations are thus acceptable, or more stations may be interposed for optimum transmission conditions. Maximum transmitter coupling requires concentration of the whole transmitted light on to the small cross-section of the respective coupling area. This is possible, for example, if a light-emissive diode or laser diode is used as the light source, the active radiating surface of which is smaller than or at most equal to the coupling-in cross-section of the reflector surface. The transmitting medium may then be merely an homogenous light guide matched to the required transmission cross-section.

In the arrangements providing directional coupling, there is a marked decoupling between the two branches, which may be significant in certain applications of the coupler system. Solid material is advantageously employed for the receiver and transmitter coupling guides, because of the low intrinsic losses, especially for short lengths. However, the receiver and transmitter diodes may also be arranged on the primary core 1,

directly opposite the respective reflector surfaces. In such a case the coupler is advantageously placed in a common housing together with the receiver and transmitter.

WHAT WE CLAIM IS:—

1. A fibre-optics T-coupler comprising a primary guide and at least one branch guide the or each branch guide extending at an angle of substantially 90° to the primary guide and a reflective surface being arranged at the position of the or each branch guide at an angle of substantially 45° to the primary guide so as to deflect, from or into the primary guide, a portion of the light transmitted along the primary guide, the deflected portion being deflected by substantially 90° into or from the branch guide at that position, and wherein at the or each branch position the primary guide comprises a one-piece element of solid transparent material extending in opposite directions away from that position and the branch comprises a one-piece element of solid transparent material extending away from that position.

2. A fibre-optics T-coupler in accordance with claim 1, wherein said one-piece element of the primary guide is formed in one side thereof, opposite the branch guide, with a triangular recess, a said reflective surface being formed on both slant surfaces of the triangular recess, so that a portion of light transmitted in either direction along the primary guide is deflected into the branch guide.

3. A fibre-optics T-coupler in accordance with claim 1, wherein for the purpose of directional separation of incoming from outgoing light there are provided on the same one-piece primary guide element two separate branch guides, each comprising a said one-piece element, the primary guide being trapezoidally recessed at about its centre, bounding surfaces at the ends of the recess forming slopes at 45° opposite the two branch guides, the long side of the recess bounding the direct optical connection between the two branch positions and the inclined bounding surfaces of the recess forming reflective said surfaces.

4. A fibre-optics T-coupler in accordance with claim 1, wherein the primary guide one-piece element is provided with a recess of rectangular form on a side thereof adjacent the branch guide, the one-piece element of the branch guide into the recess and having at least one said reflective surface formed on its end in that recess.

5. A fibre-optics T-coupler in accordance with claim 4, wherein for the purpose of directional separation of incoming from outgoing light two separate branch guides are provided each comprising a said one-piece element, which elements extend into the rectangular recess and are in contact with the surfaces thereof which bound it in the direction of light transmission through the primary guide, the end surfaces of said branch guide one-piece element being inclined at 45° to form said reflective surfaces.

6. A fibre-optics T-coupler in accordance with claim 1, for directional separation of incoming from outgoing light, wherein two said reflective surfaces, inclined at 45° to the direction of light passing therethrough, are disposed concentrically within the primary guide.

7. A fibre-optics T-coupler in accordance with claim 6, wherein the primary guide one-piece element is pierced by an aperture perpendicular to the direction of light passing through the primary guide respective branch guide one-piece elements having end faces inclined at 45° to their length being introduced into the aperture and disposed so as respectively to reflect light between said primary guide and said branch guides.

8. A fibre-optics T-coupler in accordance with claim 7, wherein a metal foil reflective on both faces is disposed between said inclined end faces.

9. A fibre-optics T-coupler in accordance with claim 7, wherein said inclined end faces are separated by air.

10. A fibre-optics T-coupler in accordance with claim 6, wherein said primary guide comprises two abutting said one-piece elements, blind bores extending from the meeting plane of said primary guide elements and the T-coupler further comprising a supporting peg disposed within said bores, a said reflective surface being formed on each end of said peg, inclined at 45° to the axis of the bores, and the T-coupler further comprising light transmissive members extending between said ends of the peg and the inner ends of said bores.

11. A fibre-optics T-coupler in accordance with claim 2, 3 or 6 or in accordance with any claim dependent upon claim 2, 3 or 6, wherein said primary guide one-piece element is cylindrical and said reflective surfaces have a convex cylindrical curvature, in the plane common to the incident and reflected light, so that in conjunction with the curvature in a plane perpendicular to said plane of the outer surface of the primary guide one-piece element they effect focussing of the light in a manner similar to a plan-convex lens

12. A fibre-optics T-coupler substantially as herein described with reference to Figures 1*a* and 1*b*, Figure 2, Figure 3*a* and 3*b*, Figure 4, Figures 5*a* and 5*b* or Figure 6 of the accompanying drawings.

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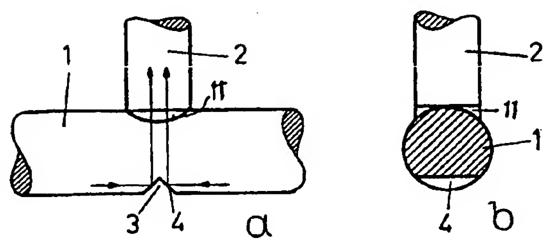

FIG.1

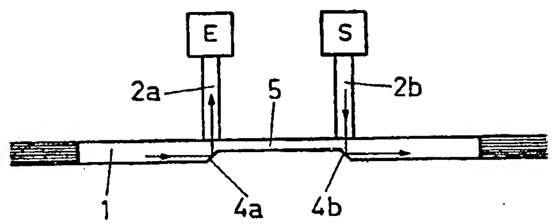

FIG. 2

1571652 COMPLETE SPECIFICATION

3 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 2

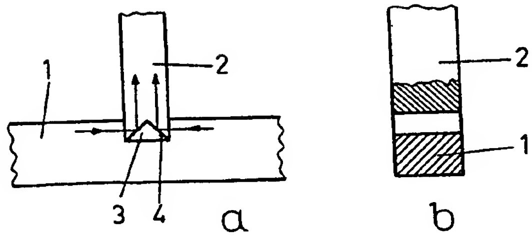

FIG. 3

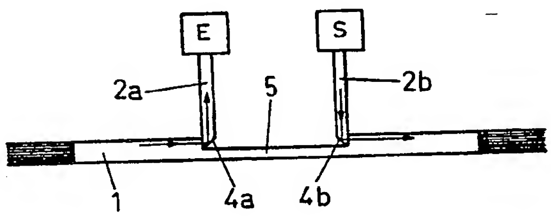

FIG. 4

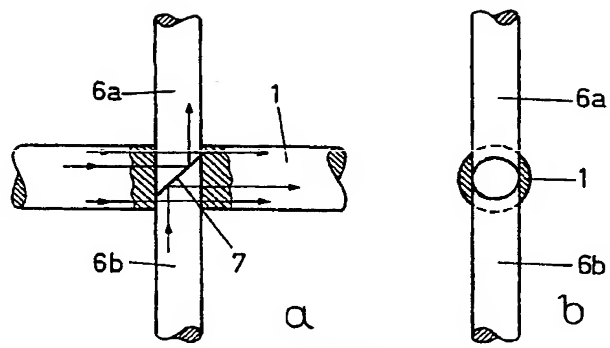

FIG.5

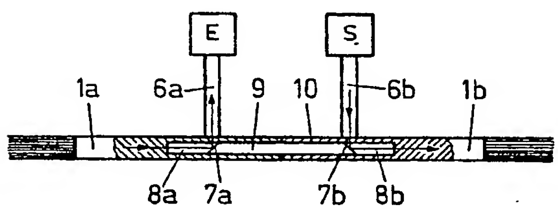

FIG.6